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U.S. Department of Energy  
Idaho Operations Office

***In Situ Bioremediation  
Interim Remedial Action Report,  
Test Area North, Operable Unit 1-07B***



Idaho National Engineering and Environmental Laboratory

**DOE/NE-ID-11221  
Revision 0  
Project No. 23339**

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**Prepared for the  
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## **ABSTRACT**

This report is an interim remedial action report for the in situ bioremediation remedial component of Operable Unit 1-07B at Test Area North at the Idaho National Laboratory. Under Environmental Protection Agency guidance, an interim report for a long-term groundwater remedial action provides a chronology of events and a description of the remedial action facilities, systems, components, and operating documents that lead to a declaration that the system is operational and functional. It is the conclusion of this report that the in situ bioremediation remedial component includes the infrastructure and programs necessary to achieve the objectives of the in situ bioremediation remedial component for contaminated groundwater in the vicinity of well TSF-05, and therefore can be deemed operational and functional.



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## ACRONYMS

AED	alternate electron donor
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
COD	chemical oxygen demand
CWSA	CERCLA waste storage area
DCE	dichloroethene
DNAPL	dense nonaqueous phase liquid
DOE	Department of Energy
DQO	data quality objective
EPA	Environmental Protection Agency
ESD	Explanation of Significant Differences
GWTF	Groundwater Treatment Facility
INL	Idaho National Laboratory
ISB	in situ bioremediation
MCL	maximum contaminant level
MNA	monitored natural attenuation
NPTF	New Pump and Treat Facility
O&M	operations and maintenance
OU	operable unit
PCE	tetrachloroethene
RAO	remedial action objective
RD/RA	remedial design/remedial action
RI/FS	remedial investigation/feasibility study
ROD	Record of Decision
TAN	Test Area North

TCE	trichloroethene
T&FR	technical and functional requirement
TPR	technical procedure
TSF	Technical Support Facility
VOC	volatile organic compound

# **In Situ Bioremediation Interim Remedial Action Report, Test Area North, Operable Unit 1-07B**

## **1. INTRODUCTION**

In situ bioremediation (ISB) is one of three remedial components selected to complete the groundwater cleanup efforts associated with Operable Unit (OU) 1-07B at Test Area North (TAN) of the Idaho National Laboratory (INL). As part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remediation activities, an ISB system was designed and constructed to remediate the Hot Spot of the contaminant plume. The ISB system injects amendment into the aquifer to enhance the growth of indigenous subsurface microorganisms that naturally dechlorinate trichloroethene (TCE), tetrachloroethene (PCE), dichloroethene (DCE), and vinyl chloride to nonhazardous compounds ethene, ethane, chloride, carbon dioxide, and water (DOE-ID 2004a).

The construction, system testing, and Agency inspection and approval of this system have been completed as documented in the *In Situ Bioremediation Final Inspection Report* (ICP 2004a). Operations of this facility will continue for an extended period of time (estimated 20 to 30 years). Continued ISB operations will meet ISB objectives before 2095.

As stated in the “Close-Out Procedures for National Priorities List Sites” (EPA 2000), an Interim Remedial Action Report may be submitted for remedies involving groundwater restoration after completion of construction activities. This Interim Remedial Action Report provides information to demonstrate that the ISB system, which consists of the ISB Injection Facility, the injection and monitoring wells, and the monitoring program, are operational and functional. This report is written to include components required by Environmental Protection Agency (EPA) guidance (EPA 2000) and is organized into the following sections:

- Introduction (Section 1)
- Description of ISB system (Section 2)
- Operational and functional determination (Section 3)
- Summary of project costs and enforceable milestones (Section 4)
- Discussion of observations and lessons learned during ISB implementation (Section 5)
- Contact information for project managers (Section 6).

## 1.1 Regulatory Background

From about 1953 to 1972, liquid wastes generated at TAN were disposed of by pumping them into the TSF-05 Injection Well in the southwest corner of the Technical Support Facility (TSF). This well dispersed the wastes into the Snake River Plain Aquifer, which underlies the INL. The wastes consisted mainly of industrial and sanitary wastewater but also included organic, inorganic, and low-level radioactive wastewaters. Activities generating these wastes included efforts to develop a nuclear-powered aircraft and tests simulating accidental loss of coolant from nuclear reactors. Contamination was discovered in 1989 and was first addressed in accordance with the *Consent Order and Compliance Agreement* (DOE-ID 1987).

In 1991, the EPA, Department of Energy (DOE), and the Idaho Department of Health and Welfare (i.e., the Agencies) entered into the *Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory* (DOE-ID 1991). As a result, contaminated groundwater that emanates from TSF-05 was designated as OU 1-07B.

A remedial investigation/feasibility study (RI/FS) was completed (EG&G 1994), which led to the approval of the *Record of Decision for the Technical Support Facility Injection Well (TSF-05) and Surrounding Groundwater Contamination (TSF-23) and Miscellaneous No Action Sites Final Remedial Action* (DOE-ID 1995). This Record of Decision (ROD) included a default remedy of pump and treat; however, it allowed for additional treatability studies to be performed that would be used to possibly determine if a more cost-effective remedy could be identified. During the performance of the treatability studies, it was made evident that the most cost-effective way to treat the contaminant plume was to divide the plume into three different zones that have distinctly different contaminant concentrations. The three zones were designated as the Hot Spot, the Medial Zone, and the Distal Zone. This distinction regarding the approach to the plume-wide cleanup process was documented in the *Explanation of Significant Differences from the Record of Decision for Technical Support Facility Injection Well (TSF-05) and Surrounding Groundwater Contamination (TSF-23) and Miscellaneous No Action Sites, Final Remedial Action* (INEEL 1997).

Completion of the treatability study process identified ISB as a more cost-effective remedy for the hot spot area and was selected as the final remedy for that zone in the *Record of Decision Amendment for the Technical Support Facility Injection Well (TSF-05) and Surrounding Groundwater Contamination (TSF-23) and Miscellaneous No Action Sites Final Remedial Action* (DOE-ID 2001a).

## 1.2 Test Area North Operable Unit 1-07B Description

Operable Unit 1-07B is the final remedial action for the TSF-05 Injection Well and the surrounding groundwater contamination located within TAN. Test Area North is one of nine major facilities at the INL (see Figure 1). The TSF-05 Injection Well is 93m (310 ft) deep and is perforated from 55 to 74 m (180 to 244 ft) and 82 to 93 m (269 to 305 ft) below ground surface. Historical records provide little definitive information on the types and volumes of organic waste disposed of into the groundwater via the injection well. It is estimated that as little as 1,325 L (350 gal) or as much as 132,489 L (35,000 gal) of TCE may have been disposed of using the injection well during its period of operation. Table 1 is a list of contaminants of concern (COCs) in the vicinity of TSF-05 that was established in the 1995 ROD (DOE-ID 1995).

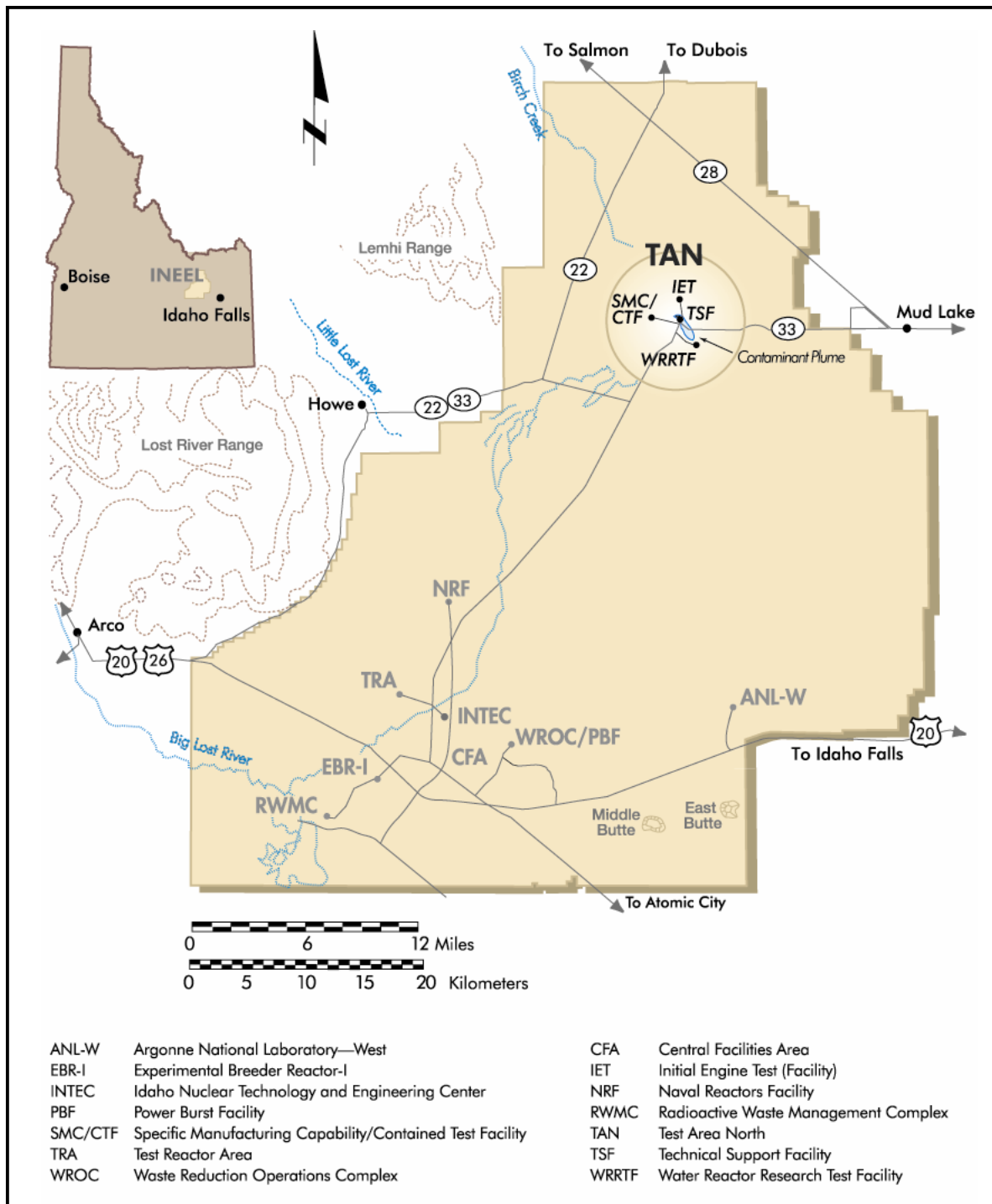


Figure 1. Map of the Idaho National Laboratory showing the location of major facilities and Test Area North.

Table 1. Contaminants of concern in the vicinity of the TSF-05 injection well (established in 1995 ROD).

Contaminant	Maximum Concentrations <sup>a</sup>	Federal Drinking Water Standard
<b>Volatile Organic Compounds</b>		
Trichloroethene (TCE)	12,000–32,000 ppb	5 ppb <sup>b</sup>
Tetrachloroethene (PCE)	110 ppb	5 ppb <sup>b</sup>
cis-1,2-Dichloroethene (DCE)	3,200–7,500 ppb	70 ppb <sup>b</sup>
trans-1,2-DCE	1,300–3,900 ppb	100 ppb <sup>b</sup>
<b>Radionuclides</b>		
Tritium	14,900–15,300 pCi/L <sup>c</sup>	20,000 pCi/L
Strontium-90	530–1,880 pCi/L	8 pCi/L
Cesium-137	1,600–2,150 pCi/L	119 pCi/L <sup>d</sup>
Uranium-234	5.2–7.7 pCi/L <sup>e</sup>	27 pCi/L <sup>e</sup>

pCi/L = picocuries per liter

ppb = parts per billion

a. The concentration range is taken from measured groundwater concentrations at the TSF-05 injection well (INEEL 1999).

b. ppb is a weight-to-weight ratio that is equivalent to micrograms per liter (µg/L) in water.

c. Maximum concentrations of tritium and U-234 are below federal drinking water standards, and baseline risk calculations indicate cancer risk of  $3 \times 10^{-6}$ . While this risk is smaller than  $1 \times 10^{-4}$ , both tritium and U-234 are included as contaminants of concern (COCs) as a comprehensive plume management strategy.

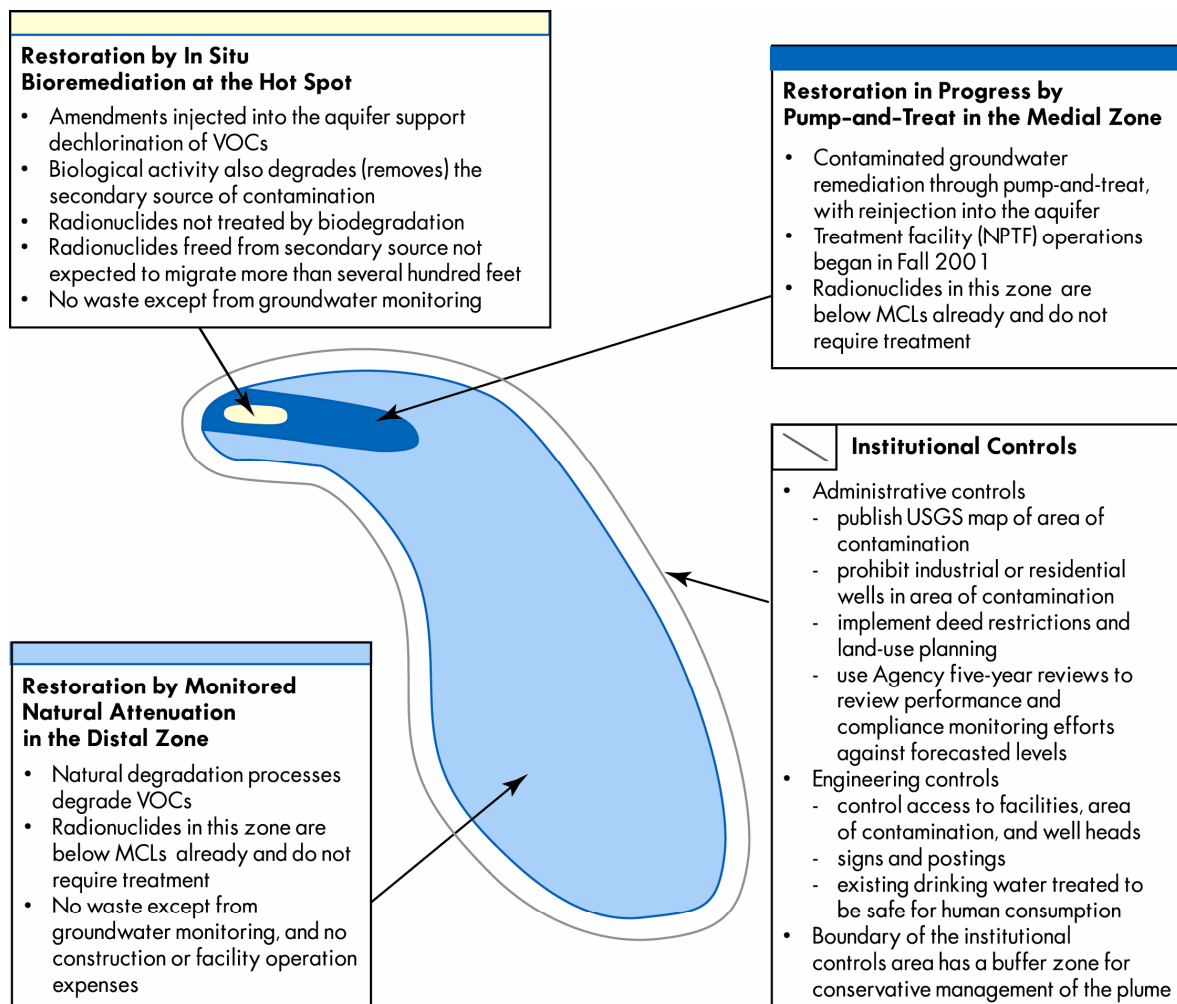
d. The maximum contaminant level (MCL) for Cs-137 is derived from a limit of 4 millirem per year (mrem/yr) cumulative dose-equivalent to the public, assuming a lifetime intake of 2 liters per day (L/day) of water.

e. The federal drinking water standard for U-234 is for the U-234, -235, and -238 series.

### 1.3 Overall Remedial Action Summary

The final remedy for OU 1-07B combines ISB for Hot Spot restoration and monitored natural attenuation (MNA) for Distal Zone restoration with pump-and-treat (selected in the 1995 ROD [DOE-ID 1995]) for the Medial Zone, providing a comprehensive approach to the restoration of the contaminant plume. The following is a description of the remedy components for restoration of the OU 1-07B Hot Spot, Medial Zone, and Distal Zone of the contaminant plume (illustrated conceptually in Figure 2) and the institutional controls, monitoring, and contingencies:

- Hot Spot**—The selected remedial component for the Hot Spot is ISB. In situ bioremediation promotes bacterial growth by supplying essential nutrients to indigenous bacteria that are able to break down contaminants within the aquifer. An amendment (i.e., sodium lactate or whey powder) is injected into the secondary source area through the TSF-05 Injection Well or through other injection wells in the immediate vicinity. Amendment injections increase the number of bacteria, thereby increasing the rate at which the volatile organic compounds (VOCs) break down into harmless compounds. The amendment supply is distributed as needed, and the treatment system operates year-round.



**Not to scale**

Figure 2. Conceptual illustration of the remedial action components.

- Medial Zone**—The selected remedy component for the Medial Zone is pump-and-treat. Pump-and-treat involves extraction of contaminated groundwater, treatment through air strippers, and injection of treated groundwater back into the aquifer. In accordance with the original remedy selected in the 1995 ROD (DOE-ID 1995), construction of the New Pump and Treat Facility (NPTF) in the Medial Zone was completed in January 2001. Routine operations for the NPTF began on October 1, 2001.
- Distal Zone**—The selected remedy component for the Distal Zone is MNA. Natural attenuation is the physical, chemical, and biological processes that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. Monitored natural attenuation includes groundwater monitoring to compare actual measured degradation rates to predicted degradation rates.

- **Institutional Controls**—Engineering and administrative controls have been put in place to protect current and future users from health risks associated with groundwater contamination. Groundwater monitoring and numerical modeling will be used to track the plume boundary; the institutional controls area will be modified, as required, to maintain a conservative buffer zone around the contaminant plume area.
- **Monitoring**—Groundwater monitoring is conducted throughout the plume, with samples analyzed to determine the progress of the remedy.
- **Contingencies**—Contingencies identified under the remedy include:
  - For the Medial Zone, monitoring wells located upgradient of the NPTF will be monitored on a routine basis to ensure that concentrations of radionuclides in the groundwater remain low. If monitoring indicates that the concentration of radionuclides in the NPTF effluent would exceed maximum contaminant levels (MCLs), the Air Stripper Treatment Unit, located between the Hot Spot and the NPTF (but not currently operating), will be used to prevent those radionuclides from traveling downgradient to the NPTF.
  - For the Distal Zone, if the Agencies determine that MNA will not restore the distal zone of the plume within the restoration timeframe, pump-and-treat units will be designed, constructed, and operated in the Distal Zone to remediate the plume. This contingency remedy will also be invoked if the required monitoring necessary for MNA is not performed.

Under the final remedy for OU 1-07B, the concentrations of the radionuclide COCs in the Hot Spot and Medial Zone will meet the remedial action objectives (RAOs) stated in the ROD (DOE-ID 1995) within the remedial timeframe through natural attenuation processes. Concentrations of the radionuclide COCs in the Distal Zone have never exceeded the RAOs. The groundwater monitoring program will include monitoring the attenuation of radionuclide COCs in the Hot Spot and the Medial Zone.

## 1.4 ISB: The Hot Spot Remedial Component

As part of the overall OU 1-07B groundwater remedial action, ISB is the final Hot Spot remedial component. The ISB remedial component involves regular injection of amendments into injection wells and monitoring groundwater throughout the Hot Spot. The ISB system, working in conjunction with naturally occurring organisms, is capable of stopping contaminant flux from leaving the Hot Spot and degrading the source within the Hot Spot. This is accomplished by creating a biologically reduced zone that encompasses the Hot Spot by injection of an electron donor, which stimulates biological activity in the aquifer.

This Interim Remedial Action Report addresses the system (as described in Section 2) needed to implement ISB in the Hot Spot area. This section provides background and description of the ISB remedial component, which is also referred to as ISB. Included in this section is a description of the ISB objectives (Section 1.4.1), governing documents (Section 1.4.2), operational phases (Section 1.4.3), and chronology of events (Section 1.4.4).

### 1.4.1 Objectives of ISB Implementation

The compliance and performance monitoring objectives for ISB consist of demonstrating meaningful progress toward restoration of the Hot Spot contaminated groundwater by 2095 (100 years from the signature of the 1995 ROD [DOE-ID 1995]) by reducing all COCs to below MCLs and a  $1 \times 10^{-4}$  total cumulative carcinogenic risk-based level for future residential groundwater use and, for noncarcinogens, until the cumulative hazard index is less than 1 (DOE-ID 2001a). These objectives will



be met through operation of the ISB system and through continued monitoring to demonstrate (1) complete dechlorination of VOCs to prevent (to the maximum extent practicable) migration of VOCs above MCLs beyond the Hot Spot, (2) degradation of the source area, and (3) restoration of the plume by 2095.

### 1.4.2 Governing Documents

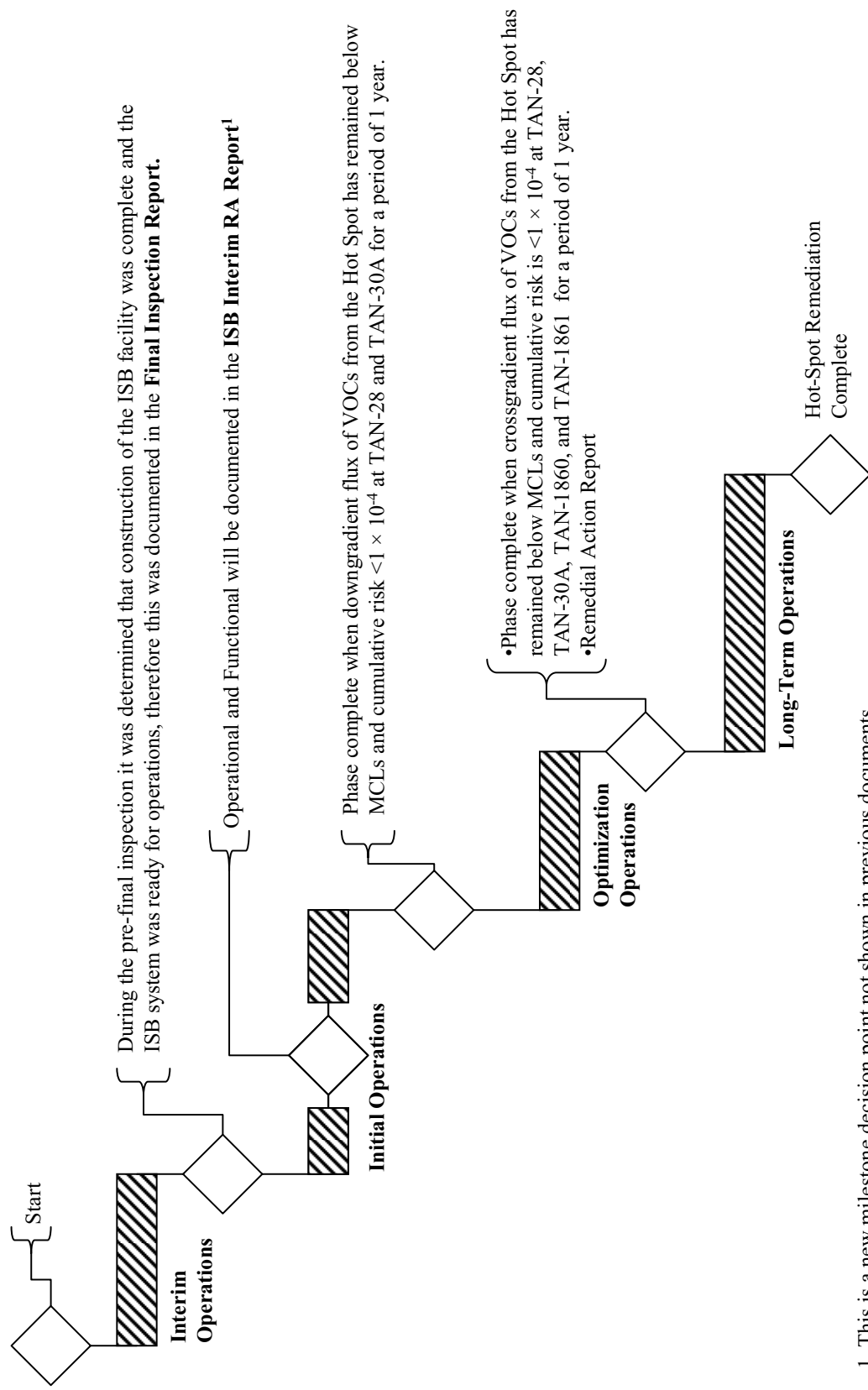
The *In Situ Bioremediation Remedial Action Work Plan for Test Area North Final Groundwater Remediation, Operable Unit 1-07B* (DOE-ID 2004b) outlines the process for implementation of ISB at TAN. The ISB Remedial Action Work Plan was developed in concert with several supporting documents to establish the basis for ISB operations. It identifies and establishes the ISB system technical and functional requirements (T&FRs), design requirements, applicable or relevant and appropriate requirements, and the requirements for operation, monitoring, and reporting. The supporting documentation provides technical methods, procedures, and protocols for implementing the requirements. Other documents that govern ISB operations and monitoring include:

- *In Situ Bioremediation Operations and Maintenance Plan for Test Area North Final Groundwater Remediation, Operable Unit 1-07B* (DOE-ID 2004a)
- *In Situ Bioremediation Remedial Action Groundwater Monitoring Plan for Test Area North, Operable Unit 1-07B* (INEEL 2003)
- *Test Area North Operable Unit 1-07B Final Groundwater Remedial Action Health and Safety Plan* (INEEL 2002b)
- *Interim Decontamination Plan for Operable Unit 1-07B* (INEEL 2002b)
- *Waste Management Plan for Test Area North Final Groundwater Remediation Operable Unit 1-07B* (INEEL 2002c).

### 1.4.3 Operational Phases

For the OU 1-07B ISB remedial component, a phased implementation strategy is being conducted for current and future activities. This implementation strategy and completion criteria are shown in Figure 3, which is modified from the ISB Remedial Action Work Plan (DOE-ID 2004b), including clarifications from the ISB O&M Plan (DOE-ID 2004a) and the addition of the ISB Interim Remedial Action Report as a milestone decision point. The implementation strategy provides a sequenced approach designed to provide the time necessary to optimize electron donor addition prior to the start of long-term operations and to monitor secondary source degradation. The ISB implementation phases are:

1. **Interim Operations**—Interim operations consist of the period of time governed by the ISB Remedial Action Work Plan before the startup of the final remedy. This phase covers activities that support a better understanding of injection strategies and electron donors.
2. **Initial Operations**—This phase is ongoing and focuses on reducing the flux of VOCs from the Hot Spot in the downgradient direction. During this phase, data are being gathered and analyzed relating to achievement of long-term performance objectives.



1. This is a new milestone decision point not shown in previous documents.

Figure 3. ISB implementation strategy.

3. Optimization Operations—This phase will focus on reducing the flux of VOCs from the Hot Spot in the crossgradient direction, while maintaining VOC flux reduction in the downgradient direction. During this phase, data will continue to be gathered and analyzed relating to achievement of long-term performance objectives.
4. Long-Term Operations—This phase will focus on achievement of Hot Spot source degradation, while maintaining the reduction of VOC flux from the Hot Spot in the crossgradient and downgradient directions.

Each phase has specific completion criteria which, when achieved, lead to the next phase or completion of the remedy component. The completion criteria for a given phase require the monitoring and evaluation of ISB performance parameters. Documents produced at various stages of implementation include the completed Final Inspection Report, this Interim Remedial Action Report, and the yet-to-be completed Remedial Action Report.

#### 1.4.4 Chronology of Events

The overall remedial action for the OU1-07B contaminant plume consists of three remedial components, as described in Section 1.3, which include the ISB remedial component. This section lists a chronology of events that led to the implementation of ISB as the Hot Spot remedial component (Section 1.4.4.1) and a summary of events that have occurred since the establishment of the ISB system and future activities, including the current projection for achieving the RAOs (Section 1.4.4.2). Table 2 lists these events and documents with the corresponding references.

Table 2. Timeline of events and documents relevant to ISB implementation.

Events	Date	Reference
Remedial Investigation	January 1994	EG&G 1994
Record of Decision	August 1995	DOE-ID 1995
RD/RA Scope of Work	August 1997	DOE-ID 1997a
OU 1-07B Explanation of Significant Differences	November 1997	INEEL 1997
Technology Evaluation Work Plan	March 1997	DOE-ID 1997b
ISB Field Evaluation Work Plan	September 1998	DOE-ID 1998
ISB Field Evaluation Report	July 2000	INEEL 2000a
Field Demonstration Report	March 2000	DOE-ID 2000
Record of Decision Amendment	September 2001	DOE-ID 2001a
RD/RA Scope of Work	November 2001	DOE-ID 2001b
ISB Operations and Maintenance Plan	July 2004	DOE-ID 2004a
ISB Remedial Action Work Plan	July 2004	DOE-ID 2004b
ISB Groundwater Monitoring Plan	January 2003	INEEL 2003
ISB Construction	March 2003 to October 2003	—
ISB Pre-Final Inspection	October 2003	ICP 2004a
ISB Final Inspection Report	October 2003	ICP 2004a
Begin Initial Operations	October 2003	ICP 2004a
Alternate Electron Donor Optimization	March 2004 <sup>a</sup>	ICP 2004b
Projection for achieving RAOs	By 2005	DOE-ID 2004b

a. Alternate electron donor optimization began in March 2004 and is ongoing.

ISB = in situ bioremediation

OU = operable unit

RAO = remedial action objective

RD/RA = remedial design/remedial action

**1.4.4.1 Events Leading to Implementation of ISB.** In 1995, a ROD was written with a requirement to conduct treatability studies focused on specific technologies that offered the potential to be more cost effective than the original remedy, which was “Hot Spot Containment and/or Removal with Aboveground Treatment.” The technologies studied included metal enhanced reductive dehalogenation, monolithic confinement, ISB, in situ chemical oxidation, and MNA. The Technology Evaluation Work Plan, Test Area North Final Groundwater Remediation, OU 1-07B (DOE-ID 1997) was established in 1997, which governed evaluation of alternatives. The results of the treatability studies, which were concluded in 1999 and summarized in the Field Demonstration Report, Test Area North Final Groundwater Remediation, Operable Unit 1-07B (DOE-ID 2000), demonstrated that the ISB technology evaluation met or exceeded all objectives and expectations. The technical success of the field evaluation, combined with the preliminary cost information, supported a recommendation to implement ISB for remediation of the Hot Spot. Therefore, in 2001 a ROD amendment was written that selected ISB to replace pump-and-treat for the hot spot area (DOE-ID 2001a).

Following the ROD Amendment, efforts began to implement ISB as the final Hot Spot remedial component. These efforts included predesign operations and development of the governing documents. Predesign operations continued ISB operations under the *In Situ Bioremediation Predesign Operations Work Plan Test Area North, Operable Unit 1-07B* (INEEL 2002d). During this time period, the governing documents discussed in Section 1.4.2 were developed as driven by the *Remedial Design/Remedial Action Scope of Work Test Area North Final Groundwater Remediation Operable Unit 1-07B* (DOE-ID 2001b), which was developed just after the completion of the ROD Amendment. These documents established programs for groundwater monitoring, electron donor injections, and institutional controls. Construction activities included installation of wells and building the ISB facility.

**1.4.4.2 Events Following Implementation of ISB.** The pre-final inspection was conducted on October 16–17, 2003. During the pre-final inspection, the regulatory agencies inspected the ISB system, including governing documents, the ISB facility, and the monitoring and injection well network. As a result of the pre-final inspection, it was concluded that construction of the ISB facility was complete and the ISB system was ready for operations. Therefore, the pre-final inspection became the final inspection and the ISB Final Inspection Report (ICP 2004a) was prepared.

Upon completion of the inspection in October 2003, initial operations began with regular injections of sodium lactate and monitoring according to the prescribed program. The injection facility was constructed to allow the injection of alternate electron donors (AEDs) such as whey powder (see Section 2.1.1). Evidence from laboratory studies suggested that whey powder might enhance performance and decrease the cost of ISB operations (ICP 2004c). As a result, initial operations included the evaluation of whey powder as an AED and potential replacement for sodium lactate (ICP 2004b). This electron donor optimization is ongoing.

In situ bioremediation operations will continue according to the phased implementation strategy summarized in Section 1.4.3. The objectives for the ISB remedial component are projected to be achieved by 2095, which is 100 years from the signature of the original ROD in 1995 (DOE-ID 2004b).

## 2. IN SITU BIOREMEDIATION SYSTEM

The ISB system is composed of the infrastructure and programs required to achieve the objectives of the ISB remedial component of the overall remedy. The ISB system includes the injection equipment, wells, ISB facility, and a monitoring program. This section provides a description of these ISB system components (Section 2.1), a synopsis of the construction (Section 2.2), a description of O&M (Section 2.3), a summary of results and findings from the final inspection (Section 2.4), and a synopsis of performance of the ISB system from startup to the present (Section 2.5).

### 2.1 Description of the ISB System

Operational resources required to implement the remedial action include personnel, physical infrastructure, and institutional controls. Physical components of the ISB system include injection wells, monitoring wells, and the ISB facility. A groundwater monitoring program has also been established to monitor the performance of ISB. This section includes a description of the ISB facility (Section 2.1.1), well network (Section 2.1.2), monitoring program (Section 2.1.3), and institutional controls (Section 2.1.4).

#### 2.1.1 ISB Facility

A new building, TAN-1614, was constructed specifically for use as the ISB facility. It is a 30- × 40-ft prefabricated building set onto a slab-on-grade concrete base. The ISB facility is divided into three areas: (1) an amendment storage (500 ft<sup>2</sup>) and process area (300 ft<sup>2</sup>), (2) a field laboratory (250 ft<sup>2</sup>), and (3) office space (150 ft<sup>2</sup>) (see Figure 4). The building is situated southeast of Well TAN-37 (see Section 2.1.2, Figure 6 for locations).

Individual areas of the ISB facility and relevant operational requirements are described in this section, including the injection equipment (Section 2.1.1.1) and the field laboratory (Section 2.1.1.2). The facility also provides office space and is used to stage up to 20 pallets of electron donor. This storage area is accessible for loading and unloading pallets through two overhead doors on either end of the building (Figure 4) and is heated in the winter to mitigate problems associated with high concentration amendment solutions that become excessively viscous at low temperatures.

**2.1.1.1 Injection Equipment.** The electron donor injection equipment is designed to mix electron donor with potable water at specific ratios and inject the resulting solution into injection wells. The In Situ Bioremediation Remedial Design, Test Area North, Operable Unit 1-07B (DOE-ID 2003) provides the design of the injection system. The following list is a summary of the general design parameters:

- The injection system provides the components needed to inject the designated amendments into wells TAN-31, TAN-1859, and TSF-05 (see Section 2.1.2 for a description of the well network)
- The system is capable of injecting the amendment solution into each of the three wells individually, at flow rates between 76 L/min (20 gpm) and 189 L/min (50 gpm)
- As a minimum, the system has the capability to inject amendment solution 10 hours/day for up to 4 days/week.
- The system is designed for a 15-year operating life

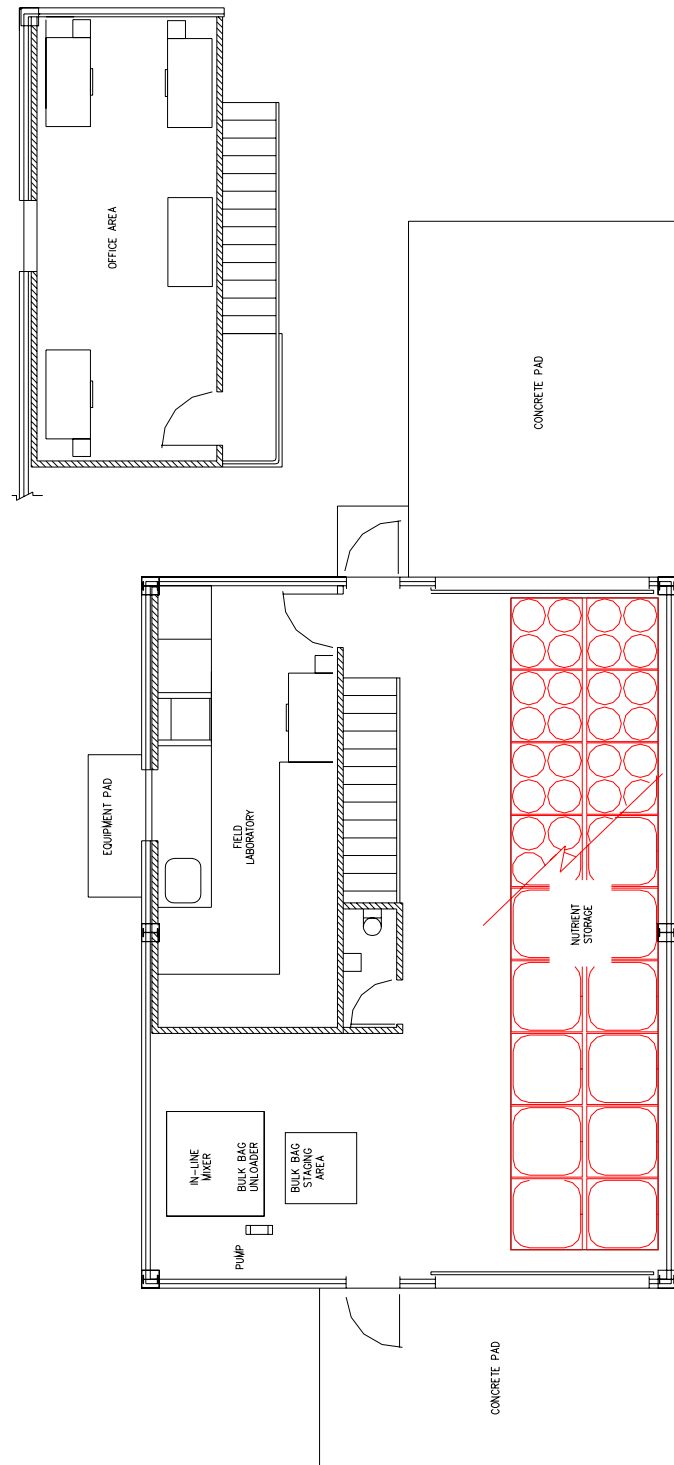


Figure 4. ISB facility layout.

- The system is capable of performing periodic injections year-round
- The system is capable of injecting sodium lactate, whey powder, or molasses.

Equipment locations within the ISB facility are shown in Figure 4. The amendment injection process flow diagram is shown in Figure 5. The injection system is comprised of a bulk bag unloader and handling system, amendment injection device (eductor or pump), flow controls, monitoring instrumentation, and piping. Injection equipment includes:

- Pressure and flow indicators
- Pressure switch
- Pump
- Bulk bag unloader (includes overhead crane and hopper)
- Eductor
- Backflow preventer
- Vacuum breaker
- Piping to injection wells.

**2.1.1.2 Field Laboratory.** The ISB facility includes a 250-ft<sup>2</sup> (23.2-m<sup>2</sup>) field laboratory used for performing field test kit analyses, sample preparations, secure sample storage, and to prepare samples for shipping/transportation. Field laboratory equipment for sample analyses includes colorimeters, reagents and standards (with appropriate storage areas), digital titrators, chemical oxygen demand (COD), digestors, alpha and beta counters, an analytical scale, pipettes, and other equipment. Equipment available for sample storage and shipping/transportation includes a refrigerator, scale, coolers, and other equipment. Safety and waste disposal equipment is also available in the field laboratory, including a fume hood, personal protective equipment, and waste containers for temporary storage of solid and liquid wastes.

## **2.1.2 ISB Well Network**

The ISB well network consists of wells used for groundwater monitoring and injection of amendments. Figure 6 illustrates the relative locations of these wells. Current amendment injection wells include TSF-05, TAN-1859, and TAN-31. This well network includes groundwater monitoring locations both inside and outside of the residual source area. Downgradient monitoring wells are strategically located to monitor flux of contaminants from the residual source area. Most wells are screened at depths approximately corresponding to the depth of the residual source area and contaminated groundwater. Well TAN-26 is screened below the residual source area, and wells TSF-05 and TAN-37 can be sampled at multiple depths.

## **2.1.3 Monitoring Program**

In order to meet the objectives of the ISB remedial component, the monitoring program is designed to collect groundwater samples to evaluate the effectiveness of source containment and removal. The monitoring program is summarized in this section. The ISB Groundwater Monitoring Plan (INEEL 2003) provides a more complete description of the program.

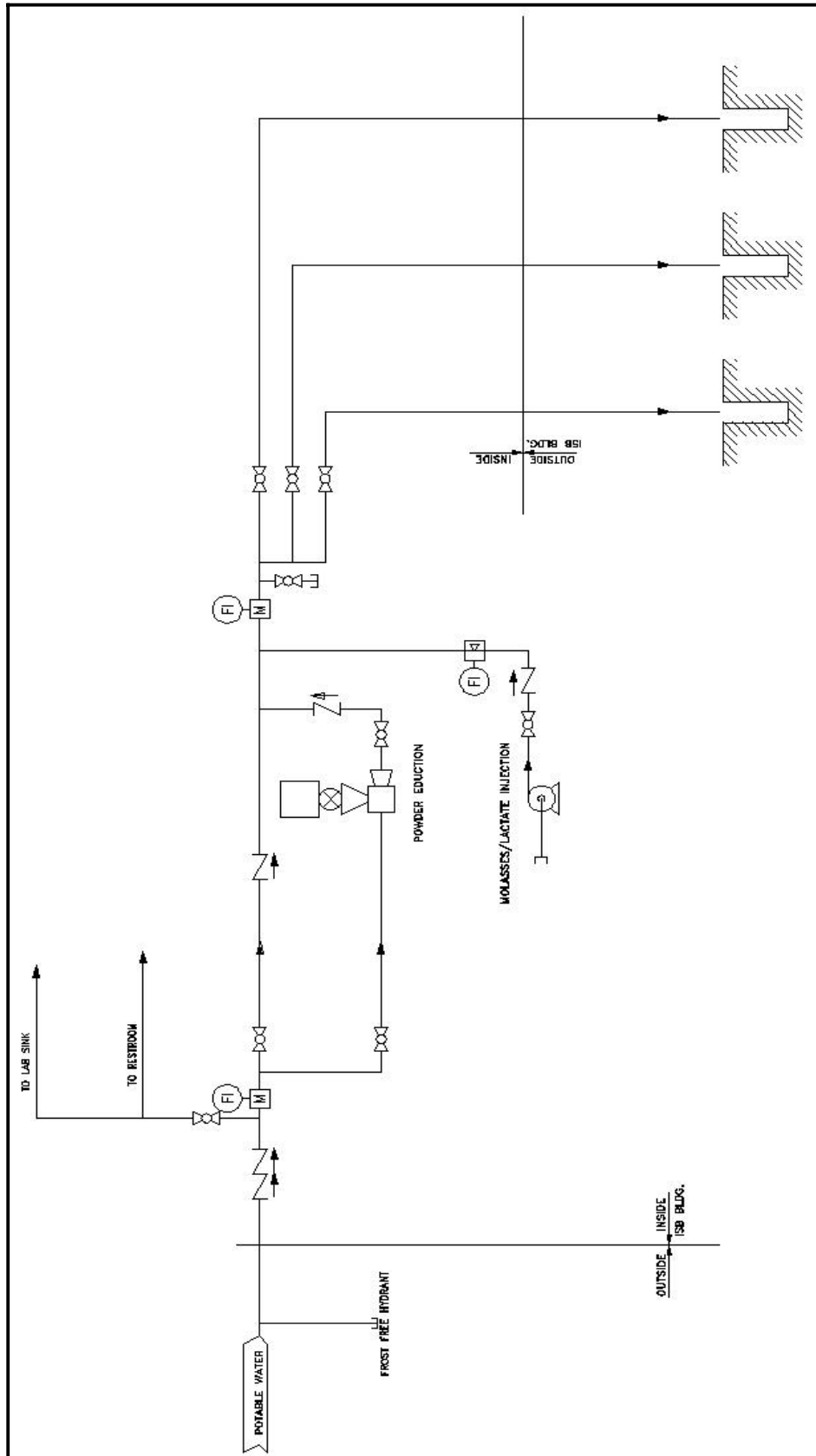
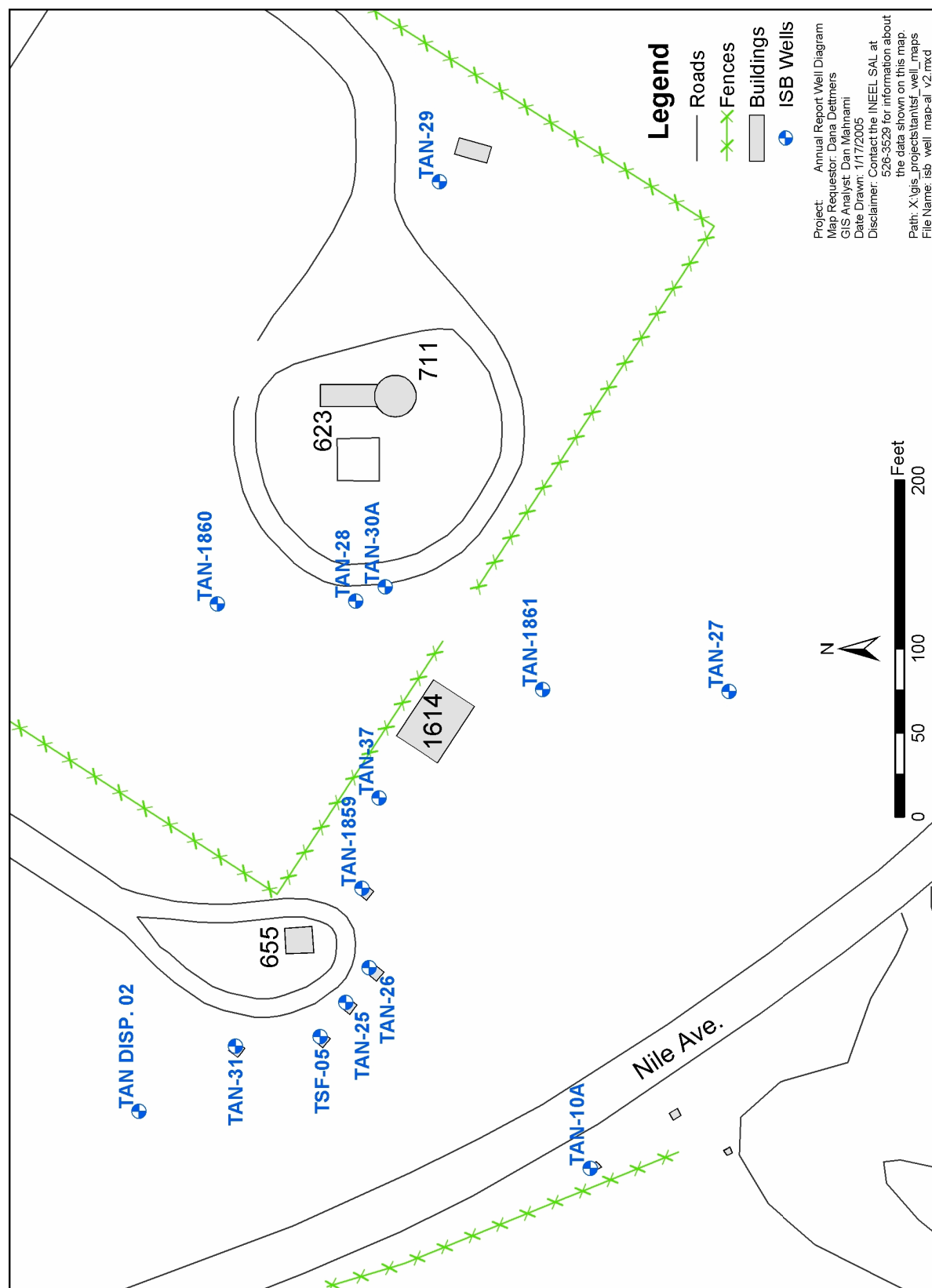


Figure 5. Process flow diagram for ISB electron donor injection system.





The groundwater monitoring program is designed to meet data quality objectives (DQOs) developed for the ISB remedial component. The DQOs are presented in detail in the ISB Remedial Action Work Plan (DOE-ID 2004b). The DQOs were prepared following EPA DQO Guidance (EPA 1994) and included consideration of method detection limits and experience with sampling and analysis methods required to support decisions on remedy performance. Data quality requirements for all INL CERCLA investigations and remedial responses are defined in the *Quality Assurance Project Plan for Waste Area Groups 1, 2, 3, 4, 5, 6, 7 and 10* (DOE-ID 2004c).

Groundwater monitoring is performed to obtain performance and compliance monitoring data to support evaluation of progress toward meeting the objectives of each implementation phase discussed in Section 1.4.3, and eventually to confirm that the ISB remedial component objectives have been achieved. In summary, the program is used to:

- Document concentration changes of COCs over time
- Provide data that will be used to perform periodic reviews and evaluations
- Evaluate progress toward meeting the RAOs established in the ROD Amendment (DOE-ID 2001a).

**2.1.3.1 Sampling Strategy.** Groundwater samples are routinely taken from the well network identified in Section 2.1.2. The sampling strategy is based on the results of the DQO process and the experience gained during pre-design operations. Two types of monitoring (performance and compliance) are defined, and a detailed discussion of the specific indicator parameters for both types of monitoring is provided in the ISB Groundwater Monitoring Plan (INEEL 2003). A summary presentation of the indicator parameters and subsequent decisions for both types of monitoring is provided in this section.

Groundwater monitoring data are required during each phase of remedy implementation to support decisions. Tables 3 and 4 portray the performance and compliance monitoring strategies, respectively, for the operational phases, including a summary of the indicator parameters to be monitored and the subsequent decisions.

**2.1.3.2 Analytes and Data Quality.** The data to be collected from groundwater sampling activities include measures of electron donor parameters, oxidation/reduction, bioactivity, anaerobic reductive dechlorination of VOCs, and radiological contaminants. These data are generated from analytical procedures used in the field laboratory, INL Research Center (IRC) laboratory, and off-Site laboratories. Detailed information on analytical methods and data management is provided in the ISB Groundwater Monitoring Plan (INEEL 2003).

The monitoring strategy includes requirements for some data to meet certain data quality levels. The data quality levels are fully defined and their application is discussed in the ISB Remedial Action Work Plan (DOE-ID 2004b). In general, definitive level data are generated using rigorous analytical methods such as approved EPA or American Society of Testing and Materials methods. Definitive data quality assurance/quality control elements include:

- Sample documentation (e.g., location, date, and time)
- Chain of custody
- Sampling design approach
- Initial and continuing calibration
- Determination and documentation of detection limits

Table 3. In situ bioremediation remedial action groundwater performance monitoring strategy summary.

Monitoring Type/Strategy Element	Operational Phase		
	Initial	Optimization	Long-Term
Decision	Determine whether operational changes are required by routinely monitoring the performance of the ISB system with respect to indicator parameters		
Monitoring locations	TSF-05A, TSF-05B, TAN-10A, TAN-25, TAN-26, TAN-27, TAN-28, TAN-29, TAN-30A, TAN-31, TAN-37A, TAN-37B, TAN-37C, and TAN-D2, TAN-1861, TAN-1860		
Monitoring frequency/ analytes	Monthly: VOCs (PCE, TCE, cis- and trans-DCE, vinyl chloride), electron donor evaluation parameters (i.e., COD, lactate or lactose, acetate, propionate, butyrate), redox parameters (ferrous iron, sulfate), bioactivity parameters (alkalinity), dissolved gases (ethene, ethane, methane), and tritium.	Quarterly: VOCs (PCE, TCE, cis- and trans-DCE, vinyl chloride), electron donors (COD, lactate, acetate, propionate, butyrate), redox parameters (ferrous iron, sulfate), bioactivity parameters (alkalinity), dissolved gases (ethene, ethane, methane), and tritium; Sr-90, Cs-137 (TAN-29 only)	
Data quality required <sup>a</sup>	Annually: Sr-90, semiannually: gamma spectrometry (Cs-137) for TAN-29 only; definitive confirmation (offsite splits) for VOCs.	Semiannual: Nutrients (ammonia-nitrogen, phosphate)	Semiannual: Nutrients (ammonia-nitrogen, phosphate)
	Semiannual: Nutrients (ammonia-nitrogen, phosphate)		Annual: Gross alpha; definitive confirmation for VOCs
	Annual: Gross alpha		
	Screening w/definitive confirmation for VOCs		
Data validation level required <sup>b</sup>	Definitive for radionuclides and definitive confirmation for VOCs		
	Screening for all other analytes		
	Level A for VOC definitive confirmation and radionuclide analyses		
No data validation for onsite and IRC laboratory data			
<p>a. Data quality levels are defined in the Quality Assurance Project Plan (DOE-ID 2004c).</p> <p>b. Data validation levels are defined in the Quality Assurance Project Plan (DOE-ID 2004c).</p> <p>COD = chemical oxygen demand  DCE = dichloroethene  IRC = INL Research Center  ISB = in situ bioremediation  PCE = tetrachloroethene  TAN = Test Area North  TCE = trichloroethene  TSF – Technical Support Facility  VOC = volatile organic compound</p>			

Table 4. In situ bioremediation remedial action groundwater compliance monitoring strategy summary.

Monitoring Type/Strategy Element	Operational Phase		
	Initial	Optimization	Long-Term
Decision	Determine whether downgradient flux of contaminants from the Hot Spot has been cut off	Determine whether crossgradient flux of contaminants from the Hot Spot has been cut off	Determine whether long-term operations are complete
Monitoring duration	1 year		TBD
Monitoring frequency	Quarterly		TBD
Monitoring locations	TAN-28 and TAN-30A	TAN-1860 and TAN-1861	TBD
Analytes	VOCs (PCE, TCE, cis- and trans-DCE, vinyl chloride)		TBD
Data quality required <sup>a</sup>	Definitive		TBD
Data validation level required <sup>b</sup>	Level A		TBD

a. Data quality levels are defined in the Quality Assurance Project Plan (DOE-ID 2004c)

b. Data validation levels are defined in the Quality Assurance Project Plan (DOE-ID 2004c)

DCE = dichloroethene  
PCE – tetrachloroethene  
TAN = Test Area North  
TBD=to be determined  
TCE = trichloroethene  
VOC = volatile organic compound

- Analyte or property identification
- Quality control blanks (field and method)
- Matrix spike recoveries
- Analytical error determination
- Total measurement error determination.

#### **2.1.4 Institutional Controls**

Institutional controls consist of engineering and administrative controls to protect current and future users from health risks associated with (1) ingestion or inhalation of, or dermal contact with, contaminants in concentrations greater than the MCLs; (2) contaminants with greater than a  $1 \times 10^{-4}$  cumulative carcinogenic risk-based concentration; or (3) a cumulative hazard index of greater than 1, whichever is more restrictive (DOE-ID 2001a). Access to water within the plume that has contaminant concentrations greater than MCLs has been placed under institutional controls until MCLs and the required risk-based concentrations are achieved.

The institutional controls for the ISB system are maintained in accordance with the *Institutional Control Plan for the Test Area North Waste Area Group 1* (INEEL 2000b) and ultimately tie into the *INEEL Sitewide Institutional Controls Plan for CERCLA Response Actions* (DOE-ID 2004d).

**2.1.4.1 Administrative Controls.** Administrative controls include written notification of this remedial action in the Sitewide Institutional Controls Plan (DOE-ID 2004d). The notification includes the following elements:

- Prohibits installation of any drinking water wells accessing the aquifer within the contaminated plume and buffer zone, as described in the ROD Amendment (DOE-ID 2001a)
- Prohibits engaging in any activities that would interfere with the remedial activity
- Legible signs placed on all groundwater wells installed within the area of contamination to indicate COCs and access restrictions.

**2.1.4.2 Engineering Controls.** Engineering controls consist of installing devices and controls to restrict access to water from within the contaminated plume. The devices include, but are not limited to, the following:

- Controlled access to the injection facility and the CERCLA waste storage areas (CWSAs) (with padlocks and locking doors)
- Controlled access to the well heads (with locking doors and/or well caps)
- Signs and postings at the ISB facility and the CWSAs (CERCLA signage is posted in accordance with 29 CFR 1910, "Occupational Safety and Health Standards")
- Postings on wellheads identifying potential hazards.

## 2.2 Construction

Construction activities associated with ISB at TAN include the construction of the ISB facility, installation of injection and monitoring wells, and construction of infrastructure to maintain institutional controls. Individual components of the ISB system are described in Section 2.1. Construction of the ISB facility began in October 2002 (DOE-ID 2004b), and the agency final inspection occurred in October 2003, as documented in the ISB Final Inspection Report (ICP 2004a).

Construction quality control requirements and design specifications are described in the ISB Remedial Design (DOE-ID 2003). In summary, construction of the ISB system complies with the local building codes, as follows:

- Code of record: *International Building Code (IBC)* 2000 edition (IBC 2000)
- IBC occupancy class: F-2
- IBC construction class: Type IIB.

## 2.3 Operation and Maintenance Strategy

This section summarizes the O&M strategy for the ISB system. All ISB operations are performed in accordance with both CERCLA and INL work control requirements. The ISB O&M Plan (DOE-ID 2004a) addresses the activities and requirements for O&M. Individual technical procedures (TPRs) specify protocols and procedures necessary for ISB system operation. Aspects of ISB operations that are summarized in this section include routine operations (Section 2.3.1), maintenance (Section 2.3.2), and waste management (Section 2.3.3).

### 2.3.1 Routine Operations

Routine operations for the ISB system include amendment injection, sampling, and field laboratory procedures. The injection system has been used to deliver both sodium lactate and whey powder as electron donors. The equipment is used to mix high concentration aqueous phase sodium lactate from 55-gal drums or 265-gal bulk containers with potable water at specific ratios. The equipment is also used to empty whey powder from 2,000-lb super sacks into the hopper and mix this solid electron donor with potable water at specific ratios. The field laboratory is routinely used during monitoring to perform field test kit analyses, sample preparations, sample storage, and to prepare samples for shipping/transportation.

Technical procedures provide guidance for routine operations of the ISB system. Individual TPRs that support routine operations of the ISB system are listed in Table 5. These include procedures used for groundwater monitoring and injection of amendments. Groundwater monitoring includes sampling, field laboratory analyses, and operation of in situ instruments. Amendment injections include startup, operation, shutdown, and system equipment inspections and routine adjustments.

Table 5. In situ bioremediation operations procedures.

ISB Operations Task	Operations Procedure
Injection of aqueous electron donor	TPR-6899, "In Situ Bioremediation Facility Aqueous Electron Donor Injection"
Injection of solid phase electron donor	TPR-6900, "In Situ Bioremediation Facility Solid Phase Electron Donor Injection"
Sampling	TPR-165, "Low Flow Groundwater Sampling Procedure"

Table 5. (continued).

ISB Operations Task	Operations Procedure
Laboratory	TPR-166, “In Situ Bioremediation Field Laboratory Procedure”
In situ instruments	TPR-6248, “OU 1-07B Hydrolab Operation and Maintenance”
In situ instruments	TPR-6247, “OU 1-07B TROLL 9000 Water Quality Probe Operations and Maintenance”
Sampling/in situ instruments/ water level measurements	TPR-4907, “Installation and Removal of Equipment in Test Area North Wells”
Training requirements	PDD-125, “OU 1-07B Test Area North Groundwater Remediation Project Training Program”
Preventative maintenance	TPR-6901, “In Situ Bioremediation Facility System Preventative Maintenance”
Inspection of safety equipment	TPR-6375, “OU 1-07B Facility Eye Wash, Emergency Light/ Exit Sign, Fire Extinguisher, and First Aid Kit Inspection Procedure”
Data management	PLN-1750, “Data Management Plan Test Area North, OU1-07B (Draft)” <sup>a</sup>

### 2.3.2 Maintenance

Procedures used for ISB maintenance activities have been developed and are listed in the ISB O&M Plan (DOE-ID 2004a). The maintenance strategy for the ISB system consists of periodic preventative maintenance and corrective maintenance, as needed. Preventative maintenance is performed on the pumps and flow control equipment, as recommended by the manufacturers. Maintenance activities for the ISB system include:

- Safety equipment inspections—Routine maintenance of eyewash bottles, portable fire extinguishers, and emergency lights, as well as the steps to be taken when an emergency indicator is triggered or abnormal conditions occur.
- Routine maintenance—Inspections and maintenance activities performed periodically on the ISB equipment.
- Corrective maintenance—Consists primarily of unplanned repairs or replacement of system components.
- Freeze protection—Measures taken after each injection event to remove all process water from the system components and piping that may otherwise be exposed to freezing.

### 2.3.3 Waste Management

The ISB Remedial Action Work Plan (DOE-ID 2004b) addresses the general requirements for all waste generated, including waste generated during O&M. The waste streams expected to be generated by ISB operations are:

a. PLN-1750, 2005, “Data Management Plan Test Area North, Operable Unit 1-07B (Draft),” Idaho Completion Project, February 2005.

- Non-hazardous CERCLA waste
- Personal protective equipment
- Sampling purge water
- Laboratory waste (hazardous and nonhazardous).

All waste generated during the operation of the ISB injection system is identified, characterized, containerized, labeled, handled, stored, and disposed of in a manner consistent with the Waste Management Plan (INEEL 2002c) and all other applicable requirements. The waste containers are inspected periodically, their locations periodically confirmed, and the waste and inspection records maintained.

## **2.4 Final Inspection**

During the pre-final inspection, it was determined that construction of the ISB facility was complete and the ISB system was ready for operations. Therefore, the pre-final inspection became the final inspection, which took place from October 16 through October 17, 2003. The ISB Final Inspection Report (ICP 2004a) documents the Agencies' concurrence that construction of the ISB facility is complete and the ISB system is ready for operations. The ISB system inspection was weighed against the operational requirements, as listed in the ISB T&FRs (TFR-2539, "Technical and Functional Requirements for the In Situ Bioremediation Design at TAN, OU 1-07B"), and was demonstrated to be able to meet these requirements. In addition to construction activities, the Agencies' inspected the governing documents described in Section 1.4.2 and confirmed that these documents were sufficient to govern activities required for ISB operations such as O&M and groundwater monitoring. Following the final inspection, the Agencies agreed that full-scale operations could begin.

## **2.5 Performance**

The ISB system meets operational requirements defined in the ISB T&FRs (TFR-2539) that will enable the ISB remedial component to meet its objectives. As documented in the ISB Final Inspection Report (ICP 2004a), after ISB construction was complete, checkout component testing was performed on the system to ensure that the equipment was properly installed and operated in accordance with the design specifications. The component testing was followed by a management self-assessment and a system operability test using potable water to demonstrate proper operation of the injection system. These activities were followed by the final inspection, which is discussed in Section 2.4. The monitoring program (including the field laboratory) has also performed according to requirements, as defined in the governing documents, and the monitoring program has been successfully used to collect data in accordance with the strategy summarized in Section 2.1.3. Minor problems associated with equipment and operations of the ISB system, documented in the ISB Final Inspection Report, have been corrected. Since operations began in October 2003, the ISB system has performed effectively.



### 3. OPERATIONAL AND FUNCTIONAL DETERMINATION

Pursuant to CERCLA regulations, “a remedy becomes ‘operational and functional’ either 1 year after construction is complete or when the remedy is determined concurrently by EPA and the state to be functioning properly and is performing as designed, whichever is earlier” (40 CFR 300.435 (f)(2), 2004). The ISB system has been operating for 1 year since the completion of the final inspection. As stated, the ISB component is comprised of the necessary programs and infrastructure required to achieve the objectives of the ISB remedial component of the overall remedial action.

The ISB system (Section 2.1) is divided into four components which include the ISB facility, ISB well network, monitoring program, and institutional controls. For each component, the actions performed during the 1-year timeframe following the final inspection in October 2003 are stated in Table 6. These actions demonstrate that the ISB system has been operating and functioning as expected for 1 year. Agency approval of this Interim Remedial Action Report will document that the ISB system is operational and functional.

Table 6. Operational and functional determination for the ISB system.

ISB System Components	Actions Performed During the 1-year Timeframe Following the ISB Final Inspection	Operational and Functional?
<b>1. ISB Facility</b>		
Injection Equipment	Periodic continuous injections: <ul style="list-style-type: none"> <li>Spaced 1 to 3 months apart</li> <li>Each injection lasted between 5 to 10 hours</li> <li>4 sodium lactate and 1 whey powder injection into TSF-05</li> <li>2 sodium lactate injections into TAN-1859.</li> </ul>	Yes
Field Laboratory	Field laboratory used to perform analyses, sample preparation, sample storage, and shipping preparations for 12 week-long sampling events and 9 single day sampling events.	Yes
<b>2. ISB Well Network</b>		
	All wells were sampled during 12 week-long events and a subset of wells was sampled during 9 single day events.	Yes
<b>3. Monitoring Program</b>		
Sampling Strategy	Performance sampling was conducted as part of the Initial Operations Phase.	Yes
Analytes and Data Quality	Samples were collected and analyses performed for all analytes, and data quality requirements were met.	Yes
<b>4. Institutional Controls</b>		
Administrative Controls	Implemented as stated in Section 2.1.4.1 of this report.	Yes
Engineering Controls	Implemented as stated in Section 2.1.4.2 of this report.	Yes

## 4. SUMMARY OF PROJECT COSTS AND ENFORCEABLE MILESTONES

This section addresses cost, schedule, and deliverables for ISB remediation activities. The OU 1-07B ROD Amendment (DOE-ID 2001a) cost estimate (see Table 7), and the assumptions contained in the ROD Amendment, may be used for comparison throughout the project. Depending on the outcome of the specified ROD and Remedial Design/Remedial Action (RD/RA) Scope of Work decision points (DOE-ID 2001b), the actual remediation costs have been within -30 to +50% of the ROD cost estimate. Also included is a cost comparison of the current project baseline and the cost estimate presented in the OU 1-07B ROD Amendment. Out-year funding availability for this project is subject to congressional approval of DOE budgets; however, the DOE has identified adequate funding in existing budget plans for this project.

Table 7. Operable Unit 1-07B remedial action cost summary.

Description	2004 Baseline Cost Estimate <sup>a,b</sup> (Using FY 1999 \$)	ROD Amendment Cost Estimate <sup>a</sup> (FY 1999 \$)
<b>In Situ Bioremediation of the Hot Spot</b>		
ISB design	152,645	9,097
ISB construction	1,178,936 <sup>c</sup>	77,871
ISB O&M (FY-04 to FY-18)	1,761,059 <sup>d</sup>	1,366,916
ISB D&D	29,692	29,692
Subtotal for ISB	3,122,332	1,483,576
Common elements (NPTF design, construction, and O&M; MNA construction and O&M; facility operations/waste management; GWTF D&D; misc. items)	18,637,368	15,091,322
Total costs incurred through FY-99	18,840,000	18,840,000
Total cost	40,599,700	35,414,898
Contingency	3,102,647	8,287,449
<b>TOTAL</b>	<b>43,702,347</b>	<b>43,702,347</b>

a. Dollars are net present value with a discount rate of 7%.

b. The baseline cost estimate includes actual cost through FY 2004 and estimated costs for FY 2005 through FY 2018 (except as noted).

c. Includes cost for office space, per the ISB RAWP, that was not included in the original cost estimate.

d. ISB O&M cost included alternate electron donor (AED) testing and evaluation.

D&D = decontamination and decommissioning

FY = fiscal year

GWTF = Groundwater Treatment Facility

ISB = in situ bioremediation

MNA = monitored natural attenuation

NPTF = New Pump and Treat Facility

O&M = Operations and Maintenance

ROD = Record of Decision

Table 8 identifies the documents and deliverables that are required by the Agencies for the ISB remedial component. This table identifies the document, document type, planned and enforceable due dates and the date the document was actually submitted. To date all required documents and deliverables for the ISB remedial component have been delivered on or ahead of schedule.

Table 8. Agency deliverable documents.

Deliverable	Planned Submittal Date	Enforceable Submittal Date	Review Duration (days)	Document Type	Actual Delivery Date
<b>Hot Spot Remediation</b>					
ISB Technical and Functional Requirements	March 2002	N/A	30	Secondary	February 21, 2002
ISB Remedial Action Work Plan	July 2002	September 2002	45	Primary	July 31, 2002
ISB Pre-final Inspection Report	January 2004	March 2004	45	Primary	January 26, 2004
ISB Interim Remedial Action Report	September 2005	N/A	45	Primary	Current document <sup>d</sup>
ISB Remedial Action Report <sup>a</sup>	TBD	TBD	45	Primary	N/A <sup>e</sup>
ISB Performance Report	May 2002	N/A	INFO	External release	May 14, 2002
O&M Plan Revision <sup>b</sup>	TBD	TBD	45	Primary	N/A <sup>e</sup>
ISB Annual Performance Report	July/yearly	N/A	INFO	External Release	2003 <sup>f</sup>
O&M Report <sup>c</sup>	TBD	TBD	45	Primary	N/A <sup>e</sup>

a. Document deliverable date (to be determined) set in the ISB Pre-final Inspection Report.

b. Deliverable date (to be determined) set in the ISB Remedial Action Report.

c. Deliverable date set in the ISB O&M Plan (DOE-ID 2004a).

d. The current document meets the requirement for the ISB Interim Remedial Action Report.

e. The planned and enforceable due dates for these documents have not been determined. The documents will be submitted when appropriate.

f. This annual report has been submitted on time since completion of the OU 1-07B RD/RA Scope of Work.

INFO = information

N/A = not applicable

O&M – Operations and Maintenance

RD/RA – remedial design/remedial action

TBD = to be determined

Figure 3 in Section 1 of this report is an illustration of the current ISB remedial component implementation schedule. This schedule illustrates the expected and agreed to outcomes for each phase of the ISB remedial component. Currently, the project is in the second year of the Initial Operations phase.

## 5. OBSERVATIONS AND LESSONS LEARNED

Observations and lessons learned from selection of the ISB remedial component, as well as construction and operation of the ISB system, can be divided into the following categories: regulatory, technical, and operational. The overall process of evaluating, selecting, and implementing bioremediation for restoration of a chlorinated solvent source area is an excellent demonstration of technical achievements that can be obtained when all stakeholders actively participate in the application of innovative technologies at the forefront of science. The following sections document the key lessons learned from before the signature of the 1995 ROD (DOE-ID 1995) through present. This is a longer timeframe than the information stated in the remainder of this report, but it is necessary to document the chronology of events leading to the operational and functional ISB system implemented at TAN that enables use of bioremediation for chlorinated solvent source area remediation.

### 5.1 Regulatory Perspective

The CERCLA regulatory process is carefully designed to provide logical and consistent guidance for conducting successful characterization, investigation, evaluation, selection, and implementation of remediation technologies. In general, the remedial investigation phase provides the opportunity to evaluate the effectiveness of technologies through treatability studies that generate the data needed to select a final remedy. Application of this process through the 70s, 80s, and early 90s resulted in identification of pump and treat as the most cost-effective technology for remediation of chlorinated solvents in groundwater. By 1995, it was recognized that pump and treat was not achieving the results that had been anticipated, and that innovative technologies needed to be found to accelerate cleanup while keeping costs comparable.

#### 5.1.1 Flexible Regulatory Process Allows Pursuit of a New Vision

The remedial project managers from the Idaho Department of Environmental Quality, the Environmental Protection Agency, and the Department of Energy jointly created a new vision for a remediation strategy that included post-ROD technology evaluations. This strategy allowed selection of the most acceptable groundwater remediation technology of the day—pump and treat—as a default remedy in the 1995 ROD (DOE-ID 1995) and included a well defined and relatively short period of time for evaluation of alternative technologies that might be more time and cost effective than pump and treat. This combined process default remedy, with parallel post-ROD innovative technology evaluations, is called “Total Plume Remediation” through application of a multicomponent remedy. The flexibility of the CERCLA process allowed incorporation of post-ROD treatability studies and provided the regulatory basis for setting scope, schedule, and deliverables to limit open-ended “technology demonstrations” or research activities not focused on an end product of overall plume remediation.

Within a year of signing the 1995 ROD, the remedial project managers prepared and approved an Explanation of Significant Differences (ESD) to identify three separate zones within the plume. This strategy was designed recognizing that (1) high concentration source areas should be addressed with more aggressive technologies; (2) intermediate concentrations could be addressed through containment or in situ technologies; and (3) the lowest concentrations could be addressed through natural attenuation processes. The ESD was a critical step in the identification of in situ bioremediation, pump and treat, and natural attenuation as the most cost- and time-effective remedy for restoration of the plume.

**Lessons Learned:** Post ROD technology evaluation is easily managed within the existing regulatory process and provides the basis for accelerated and successful innovative technology evaluations. Use of the ESD process to segregate the plume into several zones allows application of multiple technologies in a combined remediation strategy that most effectively addresses groundwater restoration over the remediation timeframe.

### 5.1.2 Public and Regulatory Acceptance of Bioremediation

In 1994, the National Academy of Science completed a review of technologies available for remediation of groundwater and concluded that TCE existing as dense nonaqueous phase liquid (DNAPL) in a deep fractured rock aquifer was the most difficult challenge in groundwater remediation, and that there were no suitable technologies for restoration (National Research Council 1994). It was recognized that pump and treat could achieve containment, but it would have to operate for hundreds of years. In the late 80s and early 90s, laboratory experiments had shown that TCE could be degraded in anaerobic environments; an intermediate step included production of vinyl chloride. Field data documenting the fate of vinyl chloride in anaerobic systems was not generally available, although it was recognized that degradation should proceed to ethane. It was also generally believed that high concentration source areas with DNAPL present would create a toxic environment for microbial communities capable of degrading TCE.

When the ROD was published in 1995, the public and regulatory community were skeptical that bioremediation would prove to be an effective technology. One or more of the reasons given above were cited to support the belief that bioremediation would have limited success. The post-ROD treatability study process focused on literature review, laboratory testing where appropriate, and primarily on field scale evaluations limited to 12 months. A panel of nationally recognized peer reviewers with expertise in each of the technologies under evaluation was convened to meet with regulators and public groups to provide a current understanding of the state-of-the-art for each technology. The peer review panel also reviewed technology field evaluation tasks to ensure that the most efficient evaluations were conducted within the schedule defined in the ROD (DOE-ID 1995). Communication of concerns, strategies, success criteria, and, ultimately, evaluation results formed the basis for public and regulatory acceptance. Communication occurred in regular meetings with the Agencies, at regularly scheduled meetings of citizen advisory groups, and onsite tours conducted for the regulators, the public, and environmental activist organizations.

**Lesson Learned:** Application of innovative technologies requires early and frequent ongoing communication. The information exchanged must be technically sound and presented in an unbiased fashion that recognizes the issues and concerns of the public and regulatory communities. Conducting innovative technology evaluations must include activities that address regulatory and public concerns.

### 5.1.3 Applied Research to Augment the Regulatory Process

A significant challenge to completing innovative technology evaluations during a remedial action is the ability to conduct forefront-of-science activities (usually called “Research”) without delaying or impeding in any way the progress of the remedial action. The regulatory agencies created the process under which these forefront-of-science activities could be conducted through incorporation of post-ROD innovative technology evaluations under a controlled schedule and in parallel with implementation of a default remedy. This process created the opportunity for national laboratory, university, and private consulting firm personnel to complete characterization or performance tests that directly supported development of the technical basis required for the regulatory and public meetings. The DOE recognized the importance of the innovative technology evaluation process and provided sufficient funding to conduct additional characterization needed to support implementation and performance monitoring for each technology evaluation. The applied research activities were integrated into the RD/RA process without disruption of ongoing remediation activity.

**Lesson Learned:** Application of innovative technologies requires the use of forefront-of-science field testing and performance monitoring to build the technical basis for acceptance, selection, and implementation. A critical component of the applied research supporting activity is the collection of technology specific site characterization data not collected during the RI/FS process.

## 5.2 Technical Perspective

Several significant technical accomplishments have been realized during the initial evaluation, subsequent optimization, and current long-term implementation of the ISB remedial component. The following subsections discuss major areas of technical achievement that have significantly impacted ISB remedy implementation at TAN and have contributed to the current body of science for implementation of ISB as a chlorinated solvent source area remedy.

### 5.2.1 Site Conceptual Model Updates

Evaluation of the ISB technology at TAN began using the information compiled during the *Remedial Investigation Final Report with Addenda for the Test Area North Groundwater Operable Unit 1-07B at the Idaho National Engineering Laboratory* (EG&G 1994). Initial research into ISB revealed that the nature and scale of the RI/FS characterization data were not adequate to implement a field study of ISB at the TAN Hot Spot. Therefore, an iterative process was employed in which a site conceptual model for the Hot Spot was created with data gaps identified. Activities were conducted to fill those data gaps and an updated conceptual model was produced incorporating the new data. This process resulted in obtaining the required characterization data for field testing of ISB and resulted in an original site conceptual model document followed by three annual updates.

**Lesson Learned:** The site conceptual model created during the RI/FS stage was compiled independent of remedies that may be implemented and, because of this, is general in nature. For ISB at TAN, new characterization data were obtained specific to the hot spot area of the plume and these new data were used to iteratively update the site conceptual model.

### 5.2.2 Enhanced Dissolution

The most important technical achievement for ISB at TAN, other than the ability to stimulate complete dechlorination of TCE to ethene, is the demonstration of enhanced dissolution of the residual source. Results obtained during the field evaluation showed that aqueous TCE concentrations increased nearly 21-fold in response to lactate injections at one TAN monitoring location and that this newly mobilized TCE was highly bioavailable. An integral part of regulatory acceptance of ISB as the Hot Spot remedy was because field data indicated that accelerated source degradation and subsequent dechlorination were achievable using ISB.

**Lesson Learned:** Proper implementation of ISB using an electron donor with enhanced dissolution properties can accelerate source area degradation compared with diffusion-limited processes.

### 5.2.3 Alternate Electron Donor Evaluation

Field testing and initial ISB optimization activities at TAN were conducted using sodium lactate as the electron donor. However, it was recognized that other electron donors may be more cost effective and/or may perform better than sodium lactate. To investigate this possibility, a series of laboratory studies was conducted. The results showed that whey powder had greater enhanced dissolution properties, stimulated comparable dechlorination efficiency, and cost less than sodium lactate and the other AEDs evaluated. Therefore, a field-scale optimization was recommended and is currently ongoing to determine

whether whey powder can replace sodium lactate as the electron donor for long-term operations of ISB at TAN.

**Lesson Learned:** Site-specific evaluation of important electron donor properties can lead to selection of a high-performance and cost-effective electron donor.

#### **5.2.4 Microbial Characterization**

Microbial characterization has been conducted as a part of ISB optimization activities at TAN. This characterization has been used to assess the effects of sodium lactate and whey powder injections in the field, as well as to assess the performance of the various alternate electron donors during the AED lab studies. Both community level characterization and species-specific methods have been used. The community level characterization has provided important information regarding shifts in the microbial community over time in response to electron donor additions. It has also revealed that competing biological reactions do not significantly hinder dechlorination efficiency and donor utilization efficiency in the TAN system. The species-specific characterization has provided the ability to track the proliferation of certain organisms that are known to perform complete dechlorination of TCE to ethene. Both types of characterization have provided valuable information that has been used to assess and even predict the response of the microbial community to operational changes.

**Lesson Learned:** Microbial characterization has allowed for the assessment of community dynamics in response to electron donor injections and has provided valuable information relating to donor utilization pathways, dechlorination efficiency, and the importance of competing biological reactions.

### **5.3 Operational Perspective**

The approximately 6 years of ISB activities at TAN have resulted in a wealth of data relating to how the system can be manipulated and the corresponding response that might be expected. This section discusses important lessons learned related to ISB operations that have resulted in significant cost savings and have increased operational efficiency.

#### **5.3.1 Amendment Delivery Systems**

Two amendment delivery systems have been used during ISB operations at TAN. The first system consisted of a simple drum pump combined with plumbing from a potable water line for injection of sodium lactate. This was a low capital cost system that required fairly intensive labor resources to operate. It was used for injection into well TSF-05 only and was capable of injecting a wide range of electron donor volumes and concentrations at variable frequencies. The second system, which has been built for long-term ISB operations, is a more complex and automated design capable of injecting both aqueous and solid phase electron donor into up to three injection wells. A key feature of this system is the ability to handle bulk containers of electron donor. This system can also be used to inject a wide range of electron donor volumes and concentrations at variable frequencies.

**Lesson Learned:** Both simple and complex designs for electron donor injection systems can be used effectively for ISB operations. A simple system involves lower capital and higher operational costs, while an automated system requires a higher capital investment but has lower operational costs and allows for more flexibility in injection strategies.

### 5.3.2 Extensive Use of Screening Data

It was recognized from the outset of ISB activities at TAN that a substantial volume of groundwater monitoring data would be required to assess the performance of ISB. It was also recognized that standard 35- to 40-day turnaround times for fixed laboratory analyses would not be adequate to make real-time operational decisions in the field, and that paying for faster turnaround times would result in very high analytical expenses. Because of this, an approach has been employed that relies on the extensive use of screening level data combined with definitive level data used for confirmation of the screening results. Specifically, field test kits, in situ data (collected with multiparameter water quality instruments), and an innovative VOC analysis (solid phase micro-extraction) are an integral part of ISB performance monitoring. This approach has resulted in the ability to cost-effectively obtain near real-time data for assessment of ISB performance for optimization of ISB operations.

**Lesson Learned:** Screening data, in situ data, and low-cost rapid turnaround on site VOC analysis allow rapid field decisions to optimize ISB system operations and reduce overall analytical cost.

### 5.3.3 Sampling and Analysis Optimization

Sampling frequency, analytes, and locations have been assessed periodically throughout ISB activities at TAN to ensure that the level of monitoring remains commensurate with the current phase of operations. In general, the amount of data required to assess ISB performance was high during the field evaluation stage and has been reduced as the ISB remedy has progressed through various stages of optimization and implementation. For example, since the field evaluation, sampling frequency has been reduced from biweekly to monthly and several field test kit and offsite split samples are no longer collected. These changes have resulted in a more cost-effective monitoring program that still provides adequate data for ISB performance assessment. The number of monitoring wells sampled and the frequency of sampling from these monitoring wells may also be decreased in the future as concentration trends following regular amendment injections are established and become more predictable.

On the other hand, sampling frequency, locations, and analytes have occasionally been increased in order to fill important data gaps. For example, in order to collect the data required to adequately compare the performance of whey powder to lactate during the AED optimization, additional sampling rounds have been added over the short term to provide the needed data.

**Lesson Learned:** The frequency, locations, and analytes included in an ISB monitoring program should be periodically evaluated to determine their utility for overall ISB operations. Eliminating unnecessary analytes, monitoring locations, and sampling rounds will result in cost savings. On the contrary, important data gaps can be filled by collecting additional data (if the need to do so is identified).



## 6. CONTACT INFORMATION

Table 9 provides contact information for project managers affiliated with the EPA, Idaho Department of Environmental Quality, DOE, and the major design and remediation contractor, Bechtel.

Table 9. List of project managers with contact information.

Name	Affiliation	Address	Phone Number
Lee Nelson	Bechtel (Design and Remediation Contractor) - Project Manager	PO Box 1625, Mail Stop 3940 Idaho Falls, Idaho 83415	(208) 526-3093
Matt Wilkening	EPA - Project Manager	1435 North Orchard Street Boise, ID 83706	(208) 378-5760
Margie English	Idaho Department of Environmental Quality - Project Manager	1410 North Hilton Boise, ID 83706-1255	(208) 373-0306
Mark Shaw	Department of Energy - Project Manager	PO Box 1625, Mail Stop 1222 Idaho Falls, Idaho 83415	(208) 526-6442

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